Seismic Evaluation of Multi-Storey Building using E-tabs

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Abstract - *Tall building or Tallness, however, is a relative matter and tall buildings cannot be defined in specific terms related just to height or to the number of floors. The tallness of a building is a matter of a person's or community's circumstance and their consequent perception. From the structural engineer's point of view, however a tall building may be defined as one that. Because of its height, is affected by lateral forces due to wind or earthquake actions to an extent that they play an important role in the structural design.*

The influence of these actions must therefore be considered from the very beginning of the design process.

In this Paper, considering the multi-storey building of G+30 floors. The various loads applied on the building such as Dead load, Live load and Earthquake load. Then analysing the behaviour of structure subjected to combination of the above mentioned loads using E-tabs software.

For the irregularity building considering the equivalent static method for different zones and soil types the clear visible that there is an increasing order in the values obtained for cumulative storey shear, displacement, storey drift and overturning moment are follows in the order of soil-I, soil-II and soil-III types in all zones in X direction. And also it comes same in the order of zone II, zone III, zone IV, zone V in all soil types in X direction.

***Key Words*: lateral forces, irregularity, storey drift, E-tabs.**

1.INTRODUCTION

Tall towers and buildings have fascinated mankind from the beginning of civilization, their construction being initially for defense and subsequently for ecclesiastical purposes. The growth in modern tall building construction, however, which began in the 1880s. Tall commercial buildings are primarily a response to the demand by business activities to be as close to each other, and to the city center, as possible, thereby putting intense pressure on the available land space. Also, because they form distinctive landmarks, tall commercial buildings are frequently developed in city centers as prestige symbols for corporate organizations. Further, the business and tourist community, with its increasing mobility, has fuelled a need for more, frequently high-rise, city center hotel accommodations. The rapid growths of the urban population and the consequent pressure on limited space have considerably influenced city residential development. The high cost of land, the desire to avoid a continuous urban sprawl, and the need to preserve important agricultural production have all contributed to drive residential buildings upward. In some cities, for example Hong Kong and Rio de Janeiro Local topographical restrictions make tall buildings the only feasible solution for housing needs.

Recently there has been a considerable increase in the number of tall buildings, both residential and commercial, and the modern trend is towards taller structures. Thus the effects of lateral loads like winds loads, earthquake forces are attaining increasing importance and almost every designer is faced with the problem of providing adequate strength and stability against lateral loads. For this reason to estimate wind load and earthquake loading on high-rise building design.

Wind speed increases at the higher levels. The dynamic responses of the wind have to be taken into consideration. There are certain methods to estimate the Static and Dynamic nature of the wind forces and have been illustrated in this paper.

1.1 IRREGULAR BUILDINGS ACCORDING TO IS CODES(1893-2002)[7]

a. Definitions of Irregular Buildings —Plan Irregularities

Torsion Irregularity to be considered when floor diaphragms are rigid in their own plan in relation to the vertical structural elements that resist the lateral forces. Torsional irregularity to be considered to exist when the maximum storey drift, computed with design eccentricity, at one end of the structures transverse to an axis is more than 1.2 times the average of the storey drifts at the two ends of the structure

b.Definition of Irregular Buildings —Vertical Irregularities

- Stiffness Irregularity —Soft Soil Storey
- A Soft Soil storey is one in which the lateral stiffness is less than 70 percent of that in the storey above or less than 80 percent of the average lateral stiffness of the three storeys above

- Stiffness Irregularity —Extreme Soft Soil Storey
- A extreme Soft Soil storey is one in which the lateral stiffness is less than 60 percent of that in the storey above or less than 70 percent of the average stiffness of the three storeys above. For example, buildings on TILTS will fall under this category,

2. OBJECTIVE

The main objective of the present work is

- To study the various load combinations on high rise buildings.
- To consider earthquake loads for G+30 storey building analysis by equivalent static analysis.
- To determine the cumulative storey shear for different zones and a soil types.
- To study the storey drift, displacement for different zones and a soil types.

3. METHODOLOGY

- In this project, considering the multi-storey building of G+30 floors. The various loads applied on the building such as Dead load, Live load and Earthquake load. Then analysing the behaviour of structure subjected to combination of the above mentioned loads using Etabs Software.

3.1 SEISMIC ANALYSIS

Seismic Analysis is a subset of structural analysis and is the calculation of the response of a building (or non-building) structure to earthquakes. It is part of the process of structural design, earthquake engineering or structural assessment and retrofit in regions where earthquakes are prevalent. A building has the potential to 'wave' back and forth during an earthquake (or even a severe wind storm). This is called the 'fundamental mode', and is the lowest frequency of building response. Most buildings, however have higher modes of response, which are uniquely activated during earthquakes.

Structural analysis methods can be divided into the following five categories.

1. Equivalent static analysis
2. Linear dynamic analysis
3. Nonlinear static analysis [pushover analysis]
4. Nonlinear dynamic analysis

Among these different types, we had chosen —Equivalent Static Analysis" as an suitable means for our project studies. From IS code for earthquake design 1893-2002[7].

Step 1: Total base shear, VB = Ah x W

Where, Ah = [Z*I*Sa/2*R*g] Design horizontal acceleration spectrum value

Z = zone factor (table 1) [7]

I = Importance factor (table 2) [7]

R= Response reduction factor (table 3) [7]

Sa/g = average response acceleration coefficient (fig 2)

W = Seismic weight of the building

Step 2: Fundamental period of vibration

[A] (Without infill)

$T = 0.075\ h^{0.75}$ for RC frame building

$T = 0.085\ h^{0.75}$ for steel frame building

[B] (With infill)

$Ta = (0.09\ h)/\ (d^{0.5})$

Where, h = Height of building

d =Base dimension of the building at the plinth level, in m.

Step 3: Distribution of seismic forces with height of the structure

$$Qi = \frac{VB\ Wi\ hi^2}{\sum Wj\ hj^2}$$

Where, Qik = Design lateral force at floor i,

Wi = Seismic weight of floor i,

Hi = Height of floor i measured from base

n = Number of storey's in the building is the number of levels at which the masses are located.

Step 4: Distribution of story forces to individual resisting elements

[A] Design lateral force at each floor in each mode:

Qik = Ai Øik Pk Wi

Where, Ai = Design horizontal acceleration spectrum value

Øik = modal shape coefficient at floor i

Pk = modal participation factor

Wi = seismic weight of floor

[B] Story shears force in each mode:

$Vik = \sum Qik$

4. MODELLING AND ANALYSIS

BASIC DATA FOR MODELLING

Wall thickness = 200 mm

Live load = 3 kN/m^2 (IS 1893 – 2002, clause 7.3.1, table 8)

Terrace live load = 1.5 kN/m^2

Floor finish = 1 kN/m^2

Floor finish for terrace = 3 kN/m^2

Time Period $(0.075H^{0.75}) = 2.25$

Importance Factor, (I) = 1

Table -1: DESCRIPTION OF STRUCTURE

No. of Floors	30 floors above ground plus terrace
Shape Of Building, Plan, Elevation whether Symmetric in Elevation	Non symmetrical building
Maximum plan dimension in either direction in mt.	B=21.7m & L=38.5m
Ratio of plan dimension	Ratio=L/B=1.77
Typical Floor to floor height in mt. Maximum floor to floor height in entire height of building in mt.	3 m 3 m
Aspect ratio (Height of building till Terrace/ Minimum Dimension of Building)	Aspect Ratio =H/B=96m/21.7m=4.42
Type of floor slab	Beam slab
Average thickness of floor slab in mm.	125mm
Whether column are RCC, Composite or In structural steel	R.C.C.
Whether the Geometry of Building is Symmetric/ Non symmetrical	Non symmetrical
Maximum cantilever projection in mt.	1.3 m

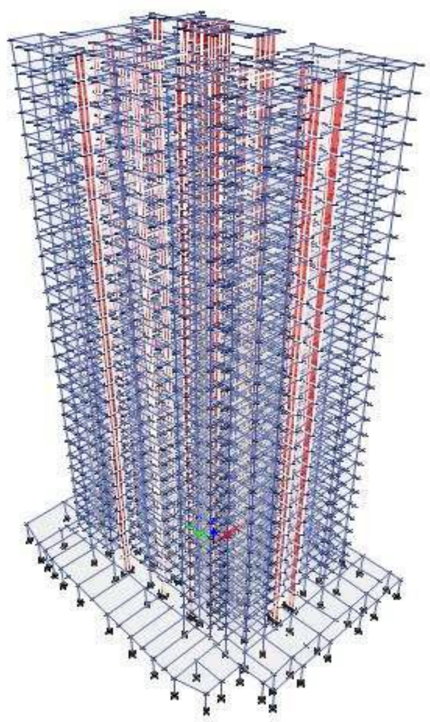

Fig -1: **3D RENDER VIEW OF G+30 (Tall Structure)**

5. RESULTS AND DISCUSSIONS

CUMULATIVE STOREY SHEAR:

Cumulative storey shear is an estimate of the maximum expected lateral force that will occur due to seismic ground motion at the base shear (V). Considering load case RESX Max has been taken for the analysis

Table -2: CUMULATIVE STOREY SHEAR V/S NO. OF STOREYS FOR ZONE-II IN X-DIRECTION

Zone-II	Hard Soil	Medium Soil	Soft Soil
Storey	V_X (kN)	V_X (kN)	V_X (kN)
31	90.6823	108.0159	121.4766
30	342.6826	417.9731	477.8396
29	566.5561	713.7039	833.5391
28	688.6724	900.3687	1076.514
27	750.7666	1016.503	1242.577
26	799.4583	1103.728	1369.178
25	860.5055	1187.846	1480.355
24	931.0174	1273.785	1583.986
23	998.7927	1357.875	1681.673
22	1060.058	1439.793	1777.461
21	1118.522	1522.225	1876.519
20	1175.62	1604.473	1979.16
19	1227.367	1681.471	2080.096
18	1270.725	1749.742	2174.179
17	1309.328	1811.93	2261.104
16	1350.332	1873.802	2343.619
15	1396.265	1937.393	2422.429
14	1442.676	1999.014	2494.855
13	1484.616	2054.518	2559.116
12	1522.437	2104.297	2617.95
11	1559.702	2152.35	2677.187
10	1596.402	2200.934	2740.482
9	1628.372	2249.338	2807.696
8	1654.901	2298.554	2878.645
7	1685.833	2355.71	2957.139
6	1736.076	2429.331	3047.509
5	1811.191	2519.675	3147.616
4	1895.137	2610.146	3241.578
3	1962.561	2678.844	3310.381
2	1996.134	2712.089	3343.032
1	2010.363	2725.879	3356.372

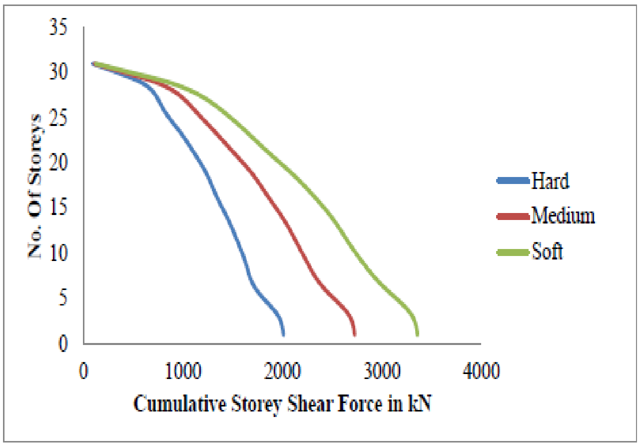

Chart -1: Graph of Cumulative storey shear v/s No. of storeys for Zone-II in X direction.

Table -2: CUMULATIVE STOREY SHEAR V/S NO. OF STOREYS FOR ZONE-III IN X-DIRECTION

Zone-III	Hard Soil	Medium Soil	Soft Soil
Storey	V_X (kN)	V_X (kN)	V_X (kN)
31	145.0465	173.2418	194.3054
30	548.1217	670.368	764.3188
29	906.2079	1144.6771	1333.2707
28	1101.5333	1444.0602	1721.9154
27	1200.8532	1630.3226	1987.5392
26	1278.7357	1770.2187	2190.0412
25	1376.3808	1905.1319	2367.8722
24	1489.1648	2042.966	2533.632
23	1597.5715	2177.8338	2689.8865
22	1695.5648	2309.218	2843.1019
21	1789.0786	2441.4278	3001.548
20	1880.4071	2573.3415	3165.7261
19	1963.1763	2696.8348	3327.175
18	2032.5281	2806.3306	3477.6641
17	2094.273	2906.0716	3616.7026
16	2159.8593	3005.3057	3748.6892
15	2233.3297	3107.296	3874.7469
14	2307.5633	3206.1264	3990.5947
13	2374.6476	3295.1474	4093.3816
12	2435.1412	3374.9855	4187.4884
11	2494.748	3452.055	4282.2411
10	2553.4492	3529.9766	4383.4827
9	2604.5851	3607.6101	4490.9931
8	2647.0177	3686.5463	4604.4777
7	2696.4936	3778.2156	4730.0324
6	2776.8586	3896.2932	4874.5812
5	2897.0046	4041.1911	5034.7056
4	3031.2768	4186.2935	5185.0005
3	3139.1207	4296.4759	5295.0528
2	3192.8211	4349.7953	5347.2792
1	3215.5801	4371.9126	5368.6168

Table -3: CUMULATIVE STOREY SHEAR V/S NO. OF STOREYS FOR ZONE-IV IN X-DIRECTION

Zone-IV	Hard Soil	Medium Soil	Soft Soil
Storey	V_X (kN)	V_X (kN)	V_X (kN)
31	217.5022	259.8626	291.4581
30	821.927	1005.552	1146.4781
29	1358.8892	1717.0156	1999.906
28	1651.7862	2166.0902	2582.8731
27	1800.7196	2445.4839	2981.3089
26	1917.5071	2655.328	3285.0619
25	2063.9293	2857.6978	3551.8082
24	2233.0526	3064.4491	3800.448
23	2395.6122	3266.7507	4034.8298
22	2542.5564	3463.827	4264.6528
21	2682.7834	3662.1416	4502.322
20	2819.7336	3860.0123	4748.5892
19	2943.8489	4045.2522	4990.7625
18	3047.8441	4209.4959	5216.4962
17	3140.4327	4359.1075	5425.0539
16	3238.7815	4507.9585	5623.0338
15	3348.9529	4660.944	5812.1203
14	3460.2687	4809.1896	5985.8921
13	3560.8638	4942.7211	6140.0725
12	3651.576	5062.4782	6281.2326
11	3740.9584	5178.0825	6423.3616
10	3828.9829	5294.9648	6575.224
9	3905.6628	5411.4152	6736.4896
8	3969.292	5529.8194	6906.7165
7	4043.4828	5667.3234	7095.0485
6	4163.9927	5844.4398	7311.8717
5	4344.1557	6061.7866	7552.0584
4	4545.5014	6279.4402	7777.5007
3	4707.2169	6444.7139	7942.5791
2	4787.7424	6524.6929	8020.9188
1	4821.8703	6557.8689	8052.9252

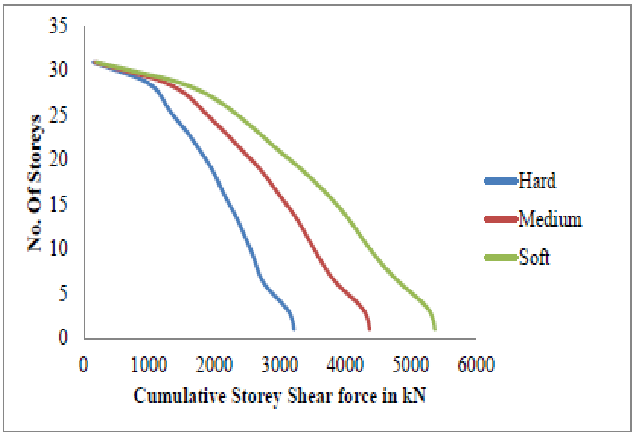

Chart -2: Graph of Cumulative storey shear v/s No. of storeys for Zone-III in X direction.

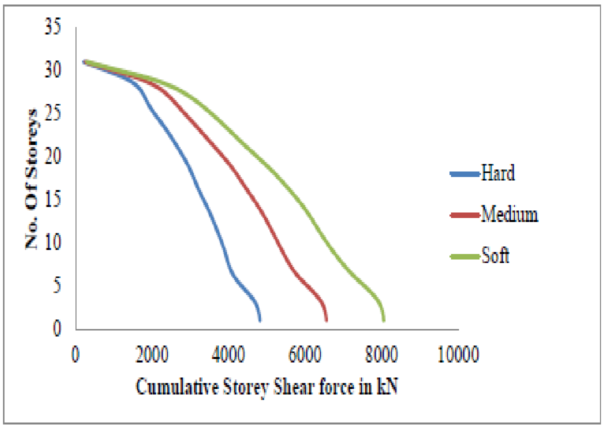

Chart -3: Graph of Cumulative storey shear v/s No. of storeys for Zone-IV in X direction.

Table -4: CUMULATIVE STOREY SHEAR V/S NO. OF STOREYS FOR ZONE-V IN X-DIRECTION

Zone-V	Hard Soil	Medium Soil	Soft Soil
Storey	V_x (kN)	V_x (kN)	V_x (kN)
31	326.2532	389.794	437.1871
30	1232.8905	1508.328	1719.7172
29	2038.3338	2575.5235	2999.8591
28	2477.6793	3249.1354	3874.3096
27	2701.0795	3668.2259	4471.9633
26	2876.2607	3982.9921	4927.5928
25	3095.8939	4286.5468	5327.7123
24	3349.5789	4596.6736	5700.672
23	3593.4182	4900.126	6052.2447
22	3813.8346	5195.7405	6396.9793
21	4024.1751	5493.2125	6753.483
20	4229.6004	5790.0184	7122.8837
19	4415.7733	6067.8783	7486.1437
18	4571.7662	6314.2439	7824.7443
17	4710.6491	6538.6612	8137.5808
16	4858.1722	6761.9377	8434.5506
15	5023.4294	6991.416	8718.1805
14	5190.403	7213.7845	8978.8381
13	5341.2957	7414.0816	9210.1087
12	5477.3639	7593.7174	9421.8489
11	5611.4376	7767.1238	9635.0424
10	5743.4743	7942.4473	9862.8361
9	5858.4942	8117.1228	10104.7344
8	5953.938	8294.7291	10360.0748
7	6065.2242	8500.9852	10642.5728
6	6245.9891	8766.6598	10967.8076
5	6516.2336	9092.6799	11328.0876
4	6818.2521	9419.1604	11666.251
3	7060.8254	9667.0709	11913.8687
2	7181.6136	9787.0394	12031.3782
1	7232.8054	9836.8034	12079.3877

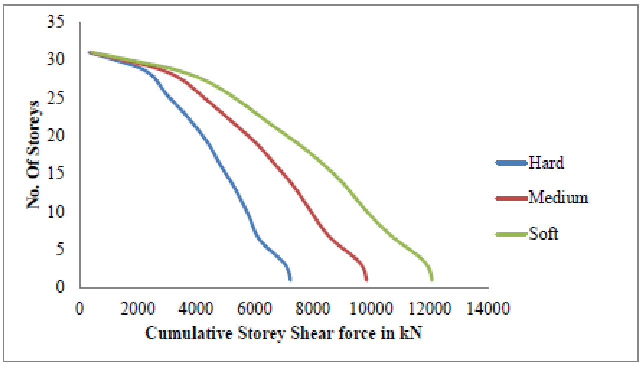

Chart -4: Graph of Cumulative storey shear v/s No. of storeys for Zone-V in X direction.

For a clear view of this increasing order in the values obtained in model for cumulative storey shear force from Etabs Software. By Plotting a graph of Cumulative storey shear v/s Number of storeys for all zones in X direction for all three different soil types namely, soil-I(Hard Soil), Soil-II(Medium Soil), Soil-III(Soft Soil) as shown in above figures, From the graph it is clearly visible that there is an increasing order in the values obtained for cumulative storey shear and follows in the order of soil-I, soil-II and soil-III types in all zones and in X direction.

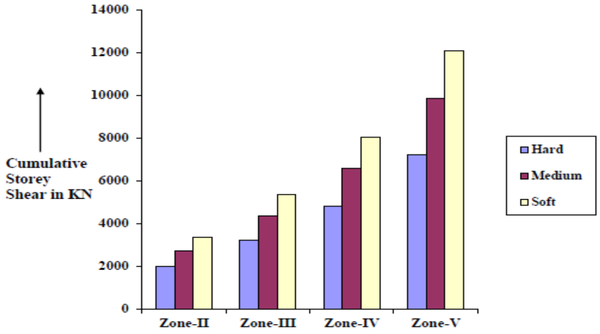

Chart -5: Cumulative Storey Shear Force v/s Zones in X Direction

Table -5: CUMULATIVE STOREY SHEAR V/S NO. OF STOREYS FOR HARD SOIL IN X-DIRECTION

HARD SOIL	ZONE-II	ZONE-III	ZONE-IV	ZONE-V
Storey	V_x (kN)	V_x (kN)	V_x (kN)	V_x (kN)
31	90.6823	145.0465	217.5022	326.2532
30	342.6826	548.1217	821.927	1232.891
29	566.5561	906.2079	1358.889	2038.334
28	688.6724	1101.533	1651.786	2477.679
27	750.7666	1200.853	1800.72	2701.08
26	799.4583	1278.736	1917.507	2876.261
25	860.5055	1376.381	2063.929	3095.894
24	931.0174	1489.165	2233.053	3349.579
23	998.7927	1597.572	2395.612	3593.418
22	1060.058	1695.565	2542.556	3813.835
21	1118.522	1789.079	2682.783	4024.175
20	1175.62	1880.407	2819.734	4229.6
19	1227.367	1963.176	2943.849	4415.773
18	1270.725	2032.528	3047.844	4571.766
17	1309.328	2094.273	3140.433	4710.649
16	1350.332	2159.859	3238.782	4858.172
15	1396.265	2233.33	3348.953	5023.429
14	1442.676	2307.563	3460.269	5190.403
13	1484.616	2374.648	3560.864	5341.296
12	1522.437	2435.141	3651.576	5477.364
11	1559.702	2494.748	3740.958	5611.438
10	1596.402	2553.449	3828.983	5743.474
9	1628.372	2604.585	3905.663	5858.494
8	1654.901	2647.018	3969.292	5953.938
7	1685.833	2696.494	4043.483	6065.224
6	1736.076	2776.859	4163.993	6245.989
5	1811.191	2897.005	4344.156	6516.234
4	1895.137	3031.277	4545.501	6818.252
3	1962.561	3139.121	4707.217	7060.825
2	1996.134	3192.821	4787.742	7181.614
1	2010.363	3215.58	4821.87	7232.805

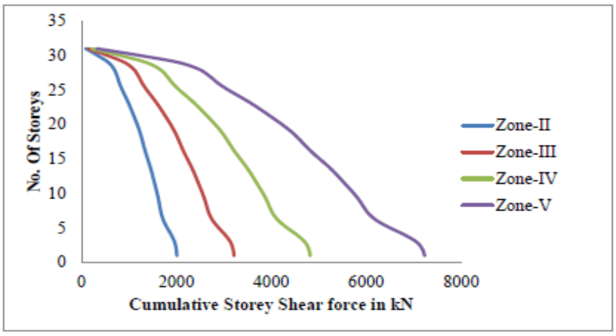

Chart -6: Graph of Cumulative storey shear v/s No. of storeys for Hard Soil in X direction.

Table -6: CUMULATIVE STOREY SHEAR V/S NO. OF STOREYS FOR MEDIUM SOIL IN X-DIRECTION

MEDIUM SOIL	ZONE-II	ZONE-III	ZONE-IV	ZONE-V
Storey	V_X (kN)	V_X (kN)	V_X (kN)	V_X (kN)
31	108.0159	173.2418	259.8626	389.794
30	417.9731	670.368	1005.552	1508.328
29	713.7039	1144.677	1717.016	2575.524
28	900.3687	1444.06	2166.09	3249.135
27	1016.503	1630.323	2445.484	3668.226
26	1103.728	1770.219	2655.328	3982.992
25	1187.846	1905.132	2857.698	4286.547
24	1273.785	2042.966	3064.449	4596.674
23	1357.875	2177.834	3266.751	4900.126
22	1439.793	2309.218	3463.827	5195.741
21	1522.225	2441.428	3662.142	5493.213
20	1604.473	2573.342	3860.012	5790.018
19	1681.471	2696.835	4045.252	6067.878
18	1749.742	2806.331	4209.496	6314.244
17	1811.93	2906.072	4359.108	6538.661
16	1873.802	3005.306	4507.959	6761.938
15	1937.393	3107.296	4660.944	6991.416
14	1999.014	3206.126	4809.19	7213.785
13	2054.518	3295.147	4942.721	7414.082
12	2104.297	3374.986	5062.478	7593.717
11	2152.35	3452.055	5178.083	7767.124
10	2200.934	3529.977	5294.965	7942.447
9	2249.338	3607.61	5411.415	8117.123
8	2298.554	3686.546	5529.819	8294.729
7	2355.71	3778.216	5667.323	8500.985
6	2429.331	3896.293	5844.44	8766.66
5	2519.675	4041.191	6061.787	9092.68
4	2610.146	4186.294	6279.44	9419.16
3	2678.844	4296.476	6444.714	9667.071
2	2712.089	4349.795	6524.693	9787.039
1	2725.879	4371.913	6557.869	9836.803

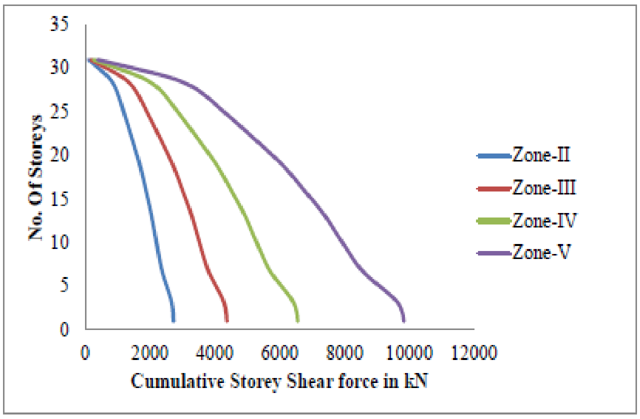

Chart -7: Graph of Cumulative storey shear v/s No. of storeys for Medium Soil in X direction.

Table -7: CUMULATIVE STOREY SHEAR V/S NO. OF STOREYS FOR SOFT SOIL IN X-DIRECTION

SOFT SOIL	ZONE-II	ZONE-III	ZONE-IV	ZONE-V
Storey	V_X (kN)	V_X (kN)	V_X (kN)	V_X (kN)
31	121.4766	194.3054	291.4581	437.1871
30	477.8396	764.3188	1146.478	1719.717
29	833.5391	1333.271	1999.906	2999.859
28	1076.514	1721.915	2582.873	3874.31
27	1242.577	1987.539	2981.309	4471.963
26	1369.178	2190.041	3285.062	4927.593
25	1480.355	2367.872	3551.808	5327.712
24	1583.986	2533.632	3800.448	5700.672
23	1681.673	2689.887	4034.83	6052.245
22	1777.461	2843.102	4264.653	6396.979
21	1876.519	3001.548	4502.322	6753.483
20	1979.16	3165.726	4748.589	7122.884
19	2080.096	3327.175	4990.763	7486.144
18	2174.179	3477.664	5216.496	7824.744
17	2261.104	3616.703	5425.054	8137.581
16	2343.619	3748.689	5623.034	8434.551
15	2422.429	3874.747	5812.12	8718.181
14	2494.855	3990.595	5985.892	8978.838
13	2559.116	4093.382	6140.073	9210.109
12	2617.95	4187.488	6281.233	9421.849
11	2677.187	4282.241	6423.362	9635.042
10	2740.482	4383.483	6575.224	9862.836
9	2807.696	4490.993	6736.49	10104.73
8	2878.645	4604.478	6906.717	10360.07
7	2957.139	4730.032	7095.049	10642.57
6	3047.509	4874.581	7311.872	10967.81
5	3147.616	5034.706	7552.058	11328.09
4	3241.578	5185.001	7777.501	11666.25
3	3310.381	5295.053	7942.579	11913.87
2	3343.032	5347.279	8020.919	12031.38
1	3356.372	5368.617	8052.925	12079.39

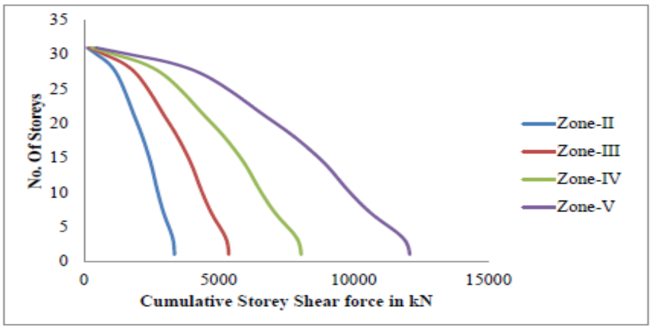

Chart -8: Graph of Cumulative storey shear v/s No. of storeys for Soft Soil in X direction.

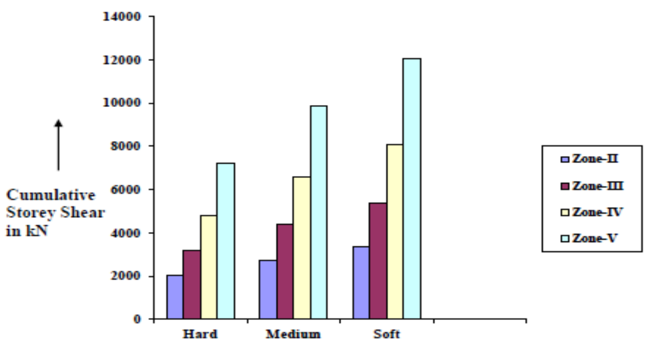

Chart -9: Cumulative Storey Shear Force v/s Soil types in X Direction

6. CONCLUSIONS

- From the above results we can conclude that, the capacity of the irregular buildings may be significant but the seismic demand varies with respect to the different zones and also different soil types.
- From the graph of equivalent static analysis, it is clearly visible that there is an increasing order in the values obtained for cumulative storey shear, displacement, storey drift and overturning moment are follows in the order of soil-I, soil-II and soil-III types in all zones in both X direction. Therefore cumulative storey shear force, displacement, storey drift and overturning moment of zones are affected by different soil types and the Soft Soil type is the critical.

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